Interim Project Lab Report

Jibin Mathews., R# 11577748

Group 16: James Panhorst, Joshua Ramirez, Alex Holmes

Texas Tech University

October 2021

Abstract

By utilizing the mini project objective of making a DC motor spin both ways, the rover can be used to autonomously follow a metallic tape around an undetermined track in a clockwise direction. The rover can also detect an obstacle that may be present within the path. From there, the alternative path has to be identified in order for the rover to follow. The rover also needs to be able to make actions to corresponding colors (ie. Red= Stop, Green= Go, Blue= Slow Down)

Table of Contents

List of Figures

List of Equations

1. Introduction

While planning the project, developing a general flow chart helped in order to better develop and analyze methods to successfully meet the objective while also being efficient. A general flowchart [Figure 1] can be structured in order to visualize the process and configuration of the project.

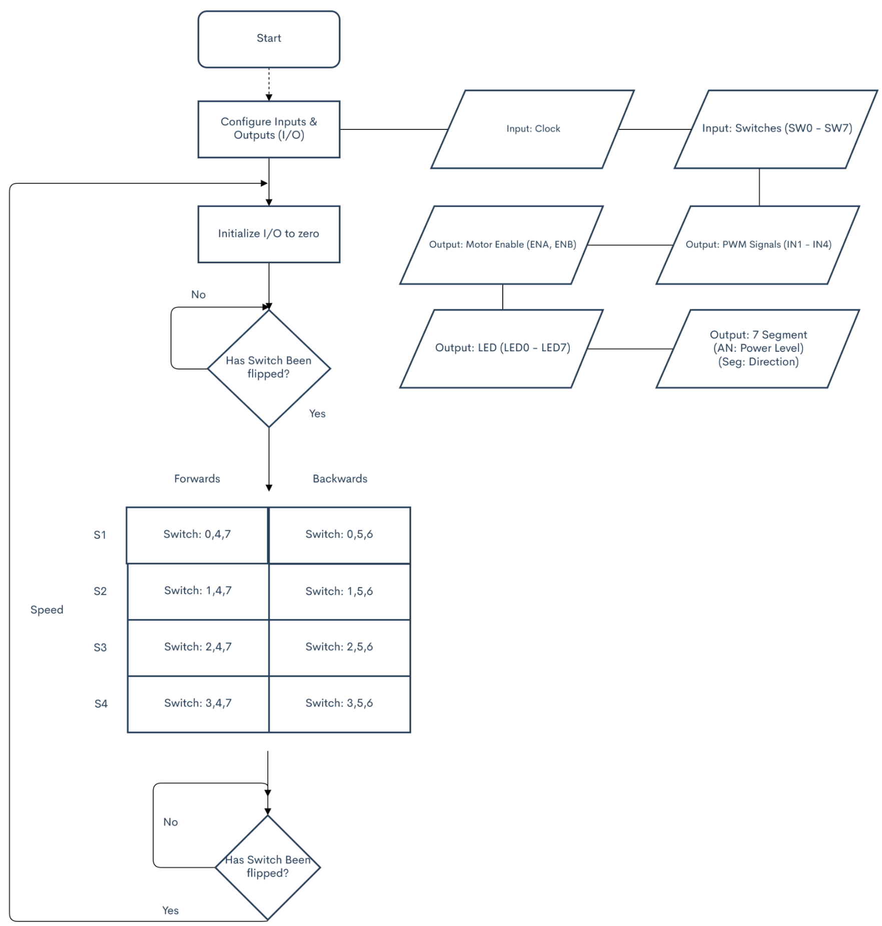


Figure 1: Mini Project General Flowchart.

From this flowchart, another flow chart [Figure 2] can be made in order to visualize the whole project by adding on to the mini project. The switches can be removed and replaced with the inputs from IPS and IR sensor in order to better control the rover under certain circumstances. The initial condition for the general flow chart entails whether the switches have been flipped. However, the main project requires the rovor to be autonomous and has to move on its own which is dependent on the color, IP, and IR sensor.

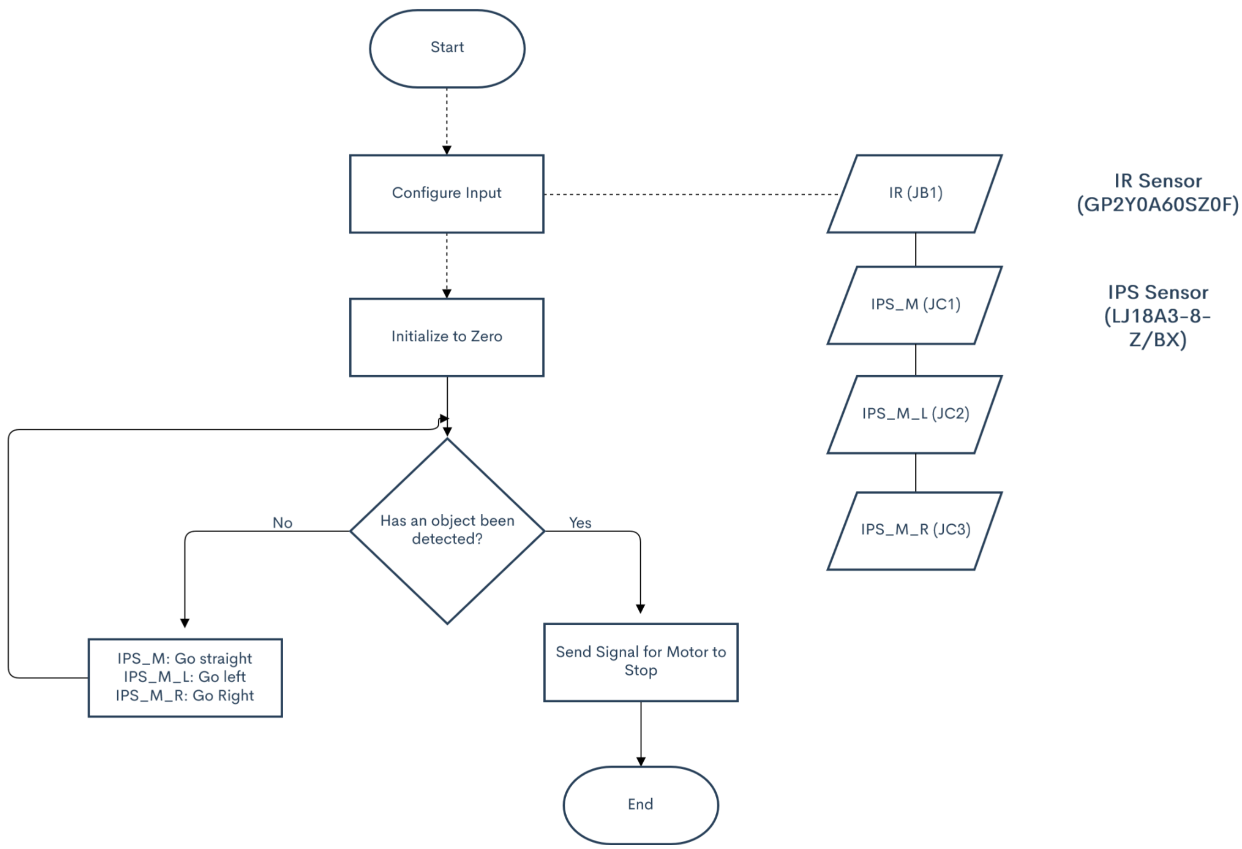


Figure 2: IPS and IR Flowchart.

The IPS and IR flow chart [Figure 2] provides a general idea of how the rover is intended to behave. Initially, all the inputs are configured such as the IR and the three IPS sensors used. The inputs are then initialized to zero. The parent code function determines whether there is an object present in front of the rover. Depending on this input the rover can either continue along the path or not move. The color sensor would be the main priority element of the code since the process requires an input of Red, green or Blue to continue with the corresponding step.

2. Components

Multiple components were used in order to achieve the objective. Specifically, the voltage regulator, comparator, optocoupler, Inductive Proximity Sensor, Infrared sensor, Light to Frequency sensor, Basys board and H-bridge. The Basys board has a limit for the maximum voltage of 5.5 volts direct current (DC) The voltage regulator (LM340T5) [Figure 3] was used in order to connect the voltage source of the 9.6 Volt battery to the basys board.

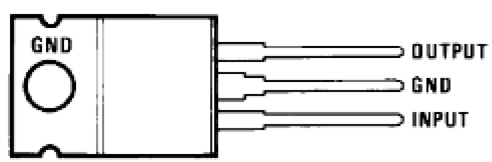


Figure 3: LM340T5 Voltage Regulator [1].

The regulator takes the input and uses a closed feedback loop in order to maintain a constant voltage for the output. The output is then directed to the basys board to provide a constant 5 Volts. Using a voltage regulator in order to connect the battery power supply to the basys board proved to be efficient and cost effective. In order to provide power for the motor and change the direction of current flow, an H-Bridge is required (L298) [Figure 4]. This component allows the change of current flow by utilizing transistors and depending on the flow, the motor will spin clockwise or counterclockwise. Utilizing the motors being able to spin in both directions is still useful for the final project since one motor has to turn in the opposite way in order to make turns.

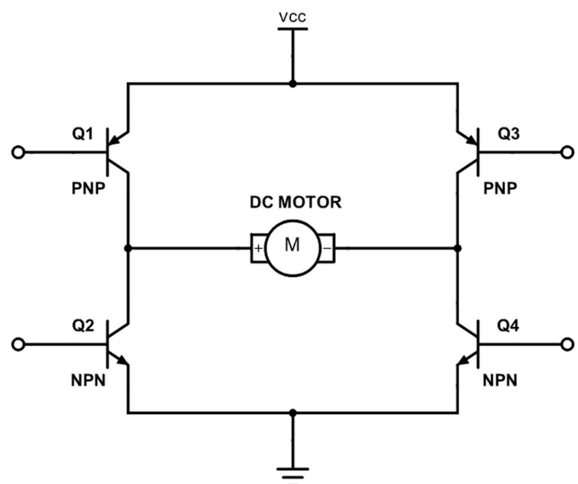


Figure 4: L298 H-Bridge [2].

The Inductive Proximity Sensor (IPS) [Figure 6] was used in order to identify the metal tape that is on the track. With an 8 millimeter (mm) detection range, the IPS sits in different locations on the rover in order to make sure it is correctly following the line. The specific Proximity sensor used is the LJ1A3-8-Z/BX which was received from the stockroom. In order to understand how the sensor is able to detect metal the schematic of the sensor should be understood.

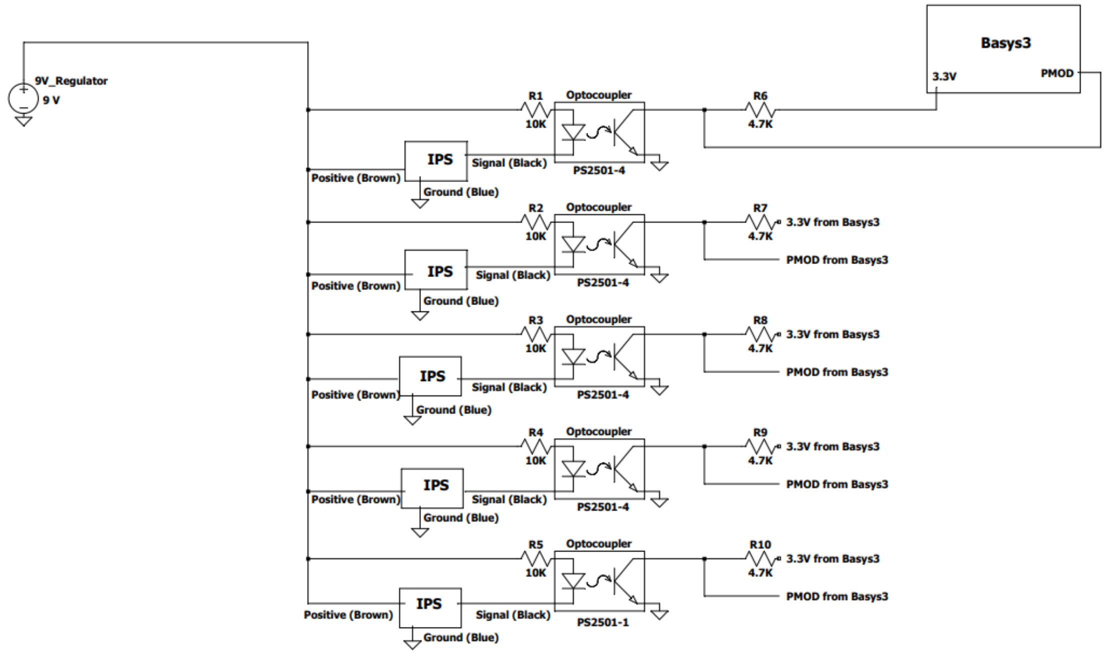


Figure 5: IPS Schematic [3].

Figure 6: LJ18A3-8-Z/BX Inductive Proximity Sensor.

The colors on the schematic represent the different wires that are available from the IPS [Figure 5]. The Brown wire signifies the positive lead, which is powered by a 9 volt regulator. The blue wire represents the ground and the black wire used as the signal wire. Within the IPS, a Bipolar Junction Transistor is used with a negative switching signal. NPN type resistors are on naturally which means whenever an object is present the signal is measured as high. While there is no object present the signal is sent low (Cook, 2021).

Within the IPS circuit an optocoupler was used in order to plug into the basys board while also maintaining a voltage that is compatible. The optocoupler [Figure 7] is used in order to transfer electrical signals through a light emitting diode often used for small circuits which require a low voltage (Jameco, n.d.). From there, a pullup resistor is used which is connected to a 3.3 Volt (DC) source. This resistor allows the outputs to be either 0 Volts for when no object is present and 3.3 Volts when an object is present. These results can be changed through the code by using an inverting function if the opposite case is required.

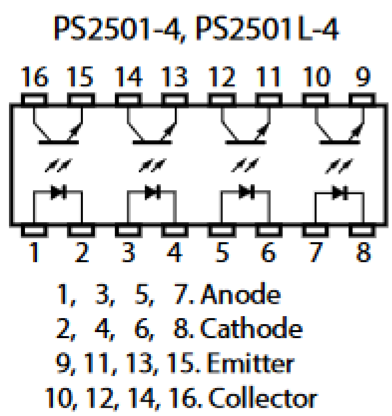


Figure 7: PS2501-4 Optocoupler [4].

Another important component utilized in the project is the comparator (LM399) [Figure 4]. The comparator is used in order to implement the software overcurrent protection and is also used to implement the IR sensor to be compared with a set value which depicts the presence of an object. The comparator essentially takes two values which are compared and outputs a digital signal of the larger signal (Basic Electronic Tutorials, 2021).

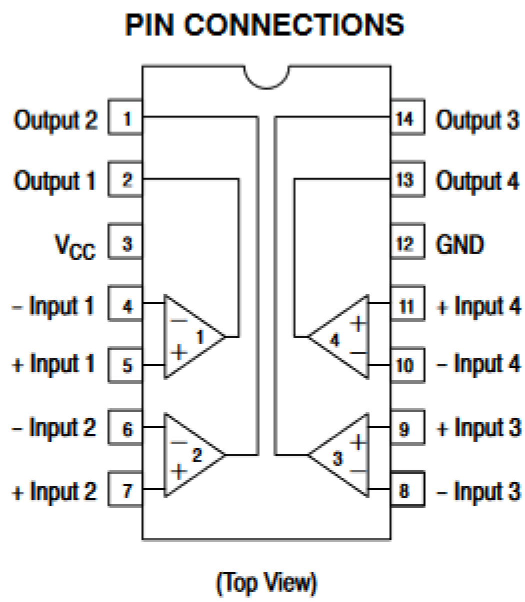


Figure 8: LM339 Quad-Comparator [5].

The specific comparator used contained four different mini comparators within the component. However, only two were required in order to compare the sensor from motor A and sensor from motor B. These sensors send a voltage to their corresponding comparator which is compared to 1 volt coming from the non- inverted portion. The calculation of the values needed can be acquired using Ohm's law equation:

$$V=R * I \tag{1}$$

Where V is represented as voltage (volts), R is represented as resistance(ohms), and I represents the current (amps). Since the input provided to the comparator as the reference is needed to be one volt, using ohm's law, it is determined that a resistance factor of one ohm is needed to achieve the current factor of one amp. If the sensor outputs more than one volt, then ideally the comparator should send the signal to ground. Otherwise, the comparator constantly monitors the voltage flow until a greater voltage is inputted. Utilizing the comparator used in the mini project, another circuit was developed for the IR Sensor.

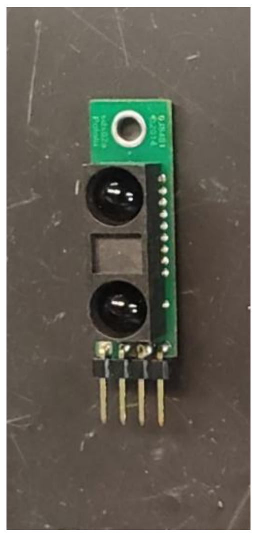


Figure 9: IR Sensor.

The Infrared Sensor (IR) (GP2Y0A60SZLF) uses a light transponder and receiver in order to determine the distance from an object that is placed in front of the sensor [Figure 9]. The specific IR sensor has a detecting range from 10 centimeters (cm) to 150 centimeters (cm). The diagram is set to have a 5 Volt input connected to Vcc directly to the IR sensor. The output is then sent to the comparator which compares the value to a 5 Volt input from the power source. This comparison is essential in order to determine if an object is present. The voltage divider with R2 and R3 are used to set the range of the IR sensors which in turn causes the IR sensor readings to be within the specified range. [Figure 10] In order to increase or decrease the range these resistor values can be changed. Another solution to change the resistor values is to implement a potentiometer which can change the resistor values without having to use individual resistors.

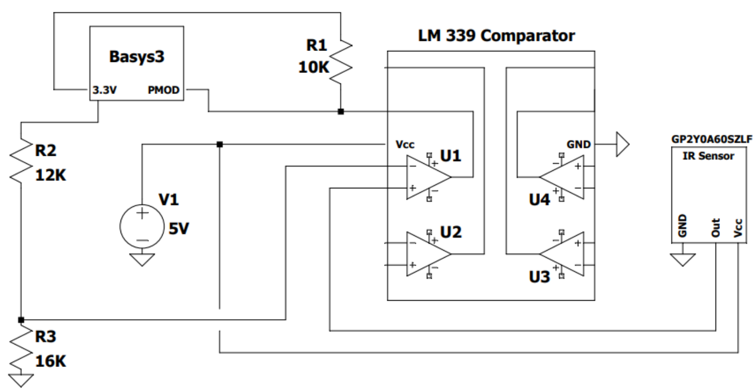


Figure 10: IR Schematic [6].

The color sensor is also used in order to determine different functioning of the rover. For example, green should make the rover go, blue should make the rover slowdown, and red should make the rover stop. The specific color sensor used for this project is the TCS 3200. The more defined term for this component is the Light to Frequency converter. The implementation is still under development due to the immense time taken to understand the physical component and the behavior of the component under different circumstances.

3. Hardware Setup

After defining and understanding the components involved within the project, the components can be combined and connected to each other in order to finalize the hardware portion of the project. Overall, the wiring seems bundled up, however, the final product will use low profile connections in order to minimize cable management and provide cleanliness.

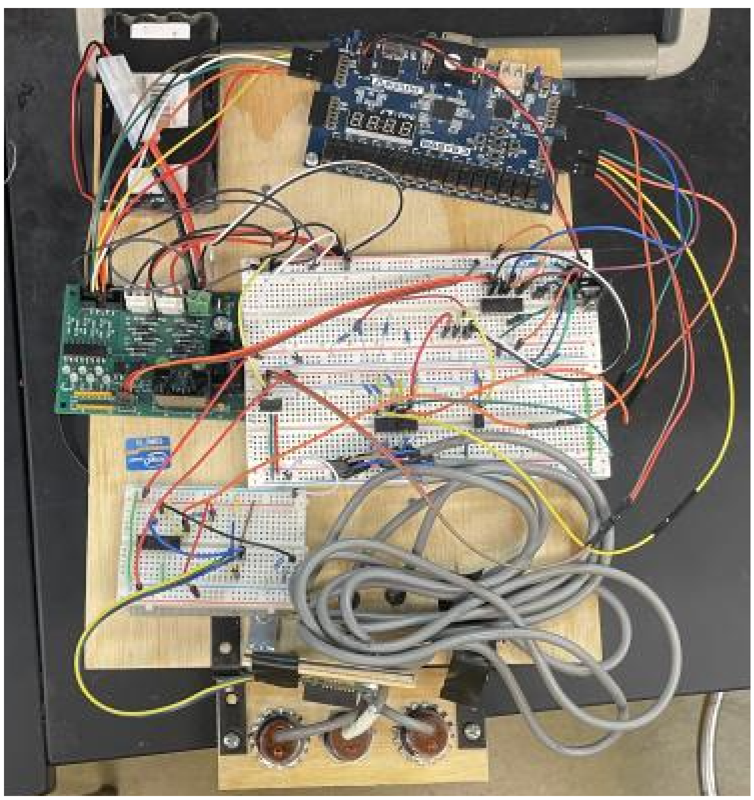


Figure 11: Hardware Circuit Diagram and Setup.

The IPS [Figure 11] is connected to the optocoupler which changes the 9 volts into a signal which is then sent to the Basys board. The signal indicates either a 0 volt or a 3.3 volts due to the pull up resistor. This indicates if there is a metallic strip present under the IPS. The IR has a similar setup, however, the output is connected to a comparator. The output from the IR sensor is an active high since the closer an object is to the sensor the higher the voltage is. The comparator takes the value from the output from the IR and uses a reference voltage to compare. The higher voltage is then sent to the Basys board. If the value from the IR sensor is sent to the board then the rover will stop. However, if the voltage is not high enough then the IR will be on standby while still sending a voltage if an object becomes present.

4. Software Flowchart

Using Figure one, the development of the code can be simplified into different portions. In the case of the project, the segments can be divided into multiple portions. Addressing the configurations of Inputs and Outputs (I/O) using switches and LEDs are an important segment to the code. Using the provided .xdc file provided by Diligent, the constraints were simple to assign different ports since they only needed to be assigned within the file. After configuring the inputs and outputs, the I/O is then initialized to zero in order to assign a beginning value to indicate no movement from the motor. The code then identifies if there is any input from the IR sensor. If an object is present within the range of the IR sensor then the rover will not move even if there is an input from the IPS. The code then goes into the next state of looking for inputs from the IPS. The program utilizes all the speeds within the table, however, the backwards portion is not available since the rover is not needed to reverse. The switch assignments are still present in order to change the speeds to follow the lines at different paces.

Switches	**0**	**1**	**2**	**3**	**4**	**5**
25% Speed Forward	1	0	0	0	1	0
50% Speed Forward	0	1	0	0	1	0
75% Speed Forward	0	0	1	0	1	0
85% Speed Forward	0	0	0	1	1	0
25% Speed Backward	1	0	0	0	0	1
50% Speed Backward	0	1	0	0	0	1
75% Speed Backward	0	0	1	0	0	1
85% Speed Backward	0	0	0	1	0	1

Figure 12: Truth Table for Rover Speed and Direction [7].

These different speeds are achieved using Pulse Width Modulation (PWM). [Figure 8] The autonomous code uses the same code as the PWM since the speeds have to vary for inputs in order to make turns and follow the set metallic tape efficiently. The code also utilizes the IR sensor by using if statements that begin the state under set conditions.

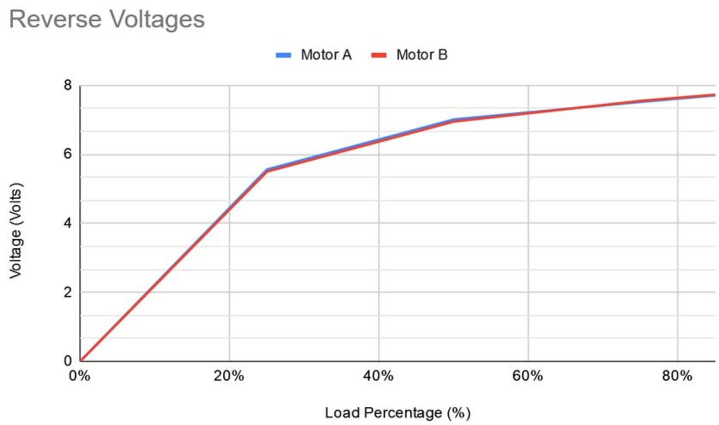
```
//      Duty cycle use in PWM:
    reg [20:0] count;// 2^(21) = 2,097,152
    reg [20:0] width;
    reg PWM;

//      Initialize values to zero
    initial begin
        count = 0;
        width = 0;
        PWM = 0;
     end

always@(posedge clock)begin
        if(count > 2097152) //resets the counter to 0 or increments
            count <= 0;
         else
            count <= count +1;

        if(count < width) begin
            PWM <= 1;
            end

        else begin
            PWM <=0;
         end
end

//      Period(Width): (2^(21)) * (Duty Cycle % / 100)
```

Figure 13: Verilog Coding: Pulse Width Modulation [8].

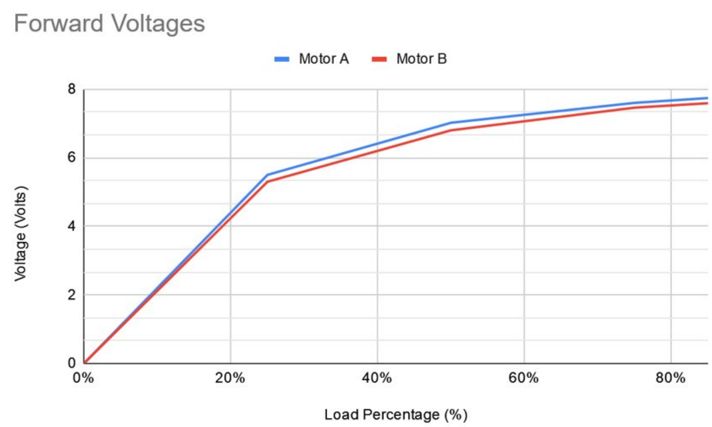
Using the PWM, the duty cycle can be assigned in order to find the clock value needed in order to power the motor at different load percentages. The equation used to find the period of the width is:

$$2^{21} * (Duty\ Cycle\ \%/\ 100) \qquad (2)$$

Using this equation, the different clock values for each speed level can be calculated in order to assign the values to the corresponding speed. In order to find the correlation between the duty cycle and the voltage, a multimeter was used in order to graph the correlation. [Figure 9] The code is set to enable the specified inputs depending on which IPS sensor was activated. Input 1 and 4 represent the forward motion while Input 2 and 3 represent backward motion. In order to make directional changes the Inputs should be alternating. For example, to turn right, Input 1 and 3 are used while left turn uses Input 2 and 4



Load Percentage (%)	Motor A Voltage (V)	Motor B Voltage (V)
0%	0	0
25%	5.56	5.5
50%	7.01	6.95
75%	7.52	7.55
85%	7.71	7.73



Load Percentage (%)	Motor A Voltage (V)	Motor B Voltage (V)
0%	0 V	0 V
25%	5.5 V	5.3 V
50%	7.02 V	6.8 V
75%	7.6 V	7.46 V
85%	7.74 V	7.59 V

Figure 14: Reverse and Forward Voltages relation to Load Percentage (%).

The graphs [Figure 13] show that the motors can have different speeds even at the same set speed. This graph explains why three IPS sensors are needed in the middle. The track can be a straight line, however, since the motor speeds vary the rover can eventually go off course. The IPS in the middle is needed in order to maintain contact with the track while the outer two keep the rover moving between the lines. For example, when the right IPS is activated the algorithm identifies that the rover is moving towards the left of the track and needs to move towards the right to keep following the line.

5. Ethics

Some ethical concerns that had occured within the project was the issue of conflict of interest. Since the individuals involved had different assignments within the project there were different viewpoints of how the hardware implementation would be carried out. For example, while deciding on the amount of IPS needed there was conflict between the coding portion and the mounting situation. Overall the conflict of interest on different aspects of the project proved to be one of the major ethical issues.

6. Safety

In terms of safety, the lab room requires proper attire in order to operate within the lab. An example was set when the Chair of the Electrical and Computer Engineering removed a student for not wearing proper attire. Safety was also used within the wood shop by using proper handwear in order to avoid splinters. Proper eyewear was also used in order to keep debris out of the eyes. Utilizing the table saw and drill press required different safety requirements in order to use.

5. Conclusion

Up to this point the utilization of different components and the understanding of each piece is important in order to implement them together. The hardware component plays an important role in the software and vice versa. The overall function of the mini project was achieved by utilizing software and hardware in order to complete the objective of using switches on the Basys board in order to control the speed and direction of the DC motor. The updated mounting [Figure 14] demonstrated the progress of utilizing and implementing code and hardware production in order to further achieve the objective.

While the IPS and IR sensors are working the only implementation missing is the color sensor and the PCB.

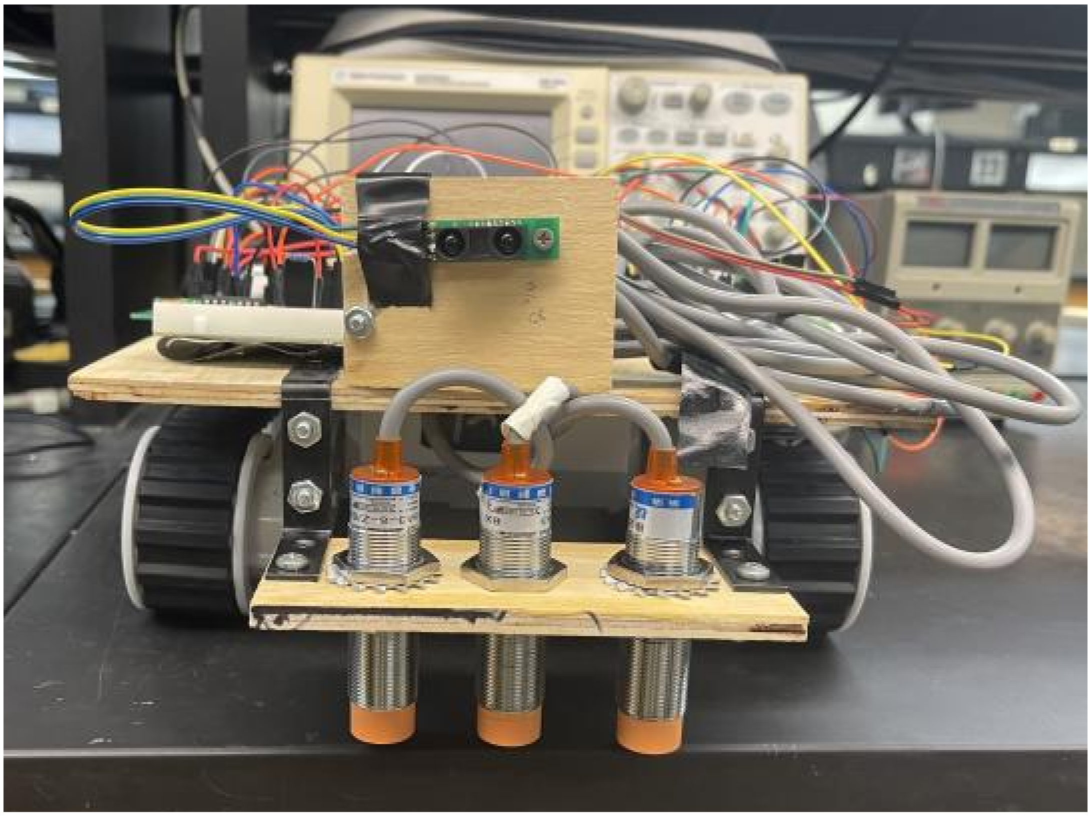


Figure 15: IPS and IR Implemented Design.

References

1. *Basys 3 FPGA Board Reference Manual*. Diligent. (2016, April 8). Retrieved September 19, 2021, from https://digilent.com/reference/_media/basys3:basys3_rm.pdf.

2. *[FPGA Tutorial] seven-segment LED display On Basys 3 Fpga*. FPGA Projects, Verilog Projects, VHDL Projects - FPGA4student.com. (n.d.). Retrieved September 20, 2021, from https://www.fpga4student.com/2017/09/seven-segment-led-display-controller-basys3-fpga.html.

3. *How to use the L298N Dual H-Bridge Motor Driver*. Banana Robotics. (n.d.). Retrieved September 20, 2021, from https://www.bananarobotics.com/shop/How-to-use-the-L298N-Dual-H-Bridge-Motor-Driver.

4. Dahl, Ø. N. (2020, June 25). *What is an H-Bridge?* Build Electronic Circuits. Retrieved September 21, 2021, from https://www.build-electronic-circuits.com/h-bridge/.

5. Cook, J. S. (2021, June 14). *NPN vs PNP: What's the difference?* Arrow.com. Retrieved October 24, 2021, from https://www.arrow.com/en/research-and-events/articles/npn-vs-pnp-in-circuit-design-and-industrial-controls.

6. *What is an Optocoupler and How it Works*. Jameco. (n.d.). Retrieved October 24, 2021, from https://www.jameco.com/Jameco/workshop/Howitworks/what-is-an-optocoupler-and-how-it-works.html.

7. *Op-amp comparator* . Basic Electronics Tutorials. (2021, March 19). Retrieved October 24, 2021, from https://www.electronics-tutorials.ws/opamp/op-amp-comparator.html.

Figures Reference:

1. Figure 3: *LM340/LM78XX Series 3-Terminal Positive Regulators*. DataSheet4U. (2006, July). Retrieved September 20, 2021, from https://datasheet4u.com/datasheet-pdf/NationalSemiconductor/LM340/pdf.php?id=49663
2. Figure 4: Dahl, Ø. N. (2020, June 25). *What is an H-Bridge?* Build Electronic Circuits. Retrieved September 21, 2021, from https://www.build-electronic-circuits.com/h-bridge/.
3. Figure 5: Panhorst, James. (2021). *IPS Schematic*. Retrieved October 24, 2021.
4. Figure 7: *PS2501-1, PS2501-4, PS2501L-1, PS2501L-4 data sheet*. (n.d.). Retrieved October 24, 2021, from https://kr.mouser.com/datasheet/2/698/REN_r08ds0202ej0100_ps2501_1_4_DST_20201225-2065566.pdf.

5. Figure 8: LM339 Reference Manual. Semiconductor Industries (2014, October) Retrieved September 20, 2021, from https://www.onsemi.com/products/signal-conditioning-control/amplifiers-comparators/comparators/lm339s.
6. Figure 10: Panhorst, J. (2021). *IR Schematic*. Retrieved September 20, 2021.
7. Figure 12: Panhorst, J. (2021). *Truth Table for Rover Speed and Direction*. Retrieved October 25, 2021.
8. Figure 13: Ramirez, J. (2021). *Verilog Coding: Pulse Width Modulation*. Retrieved October 25, 2021.

Appendix A

Budget

Project Lab 1	Current Totals			Estimated Total				Start Date	8/23/21
Direct Labor	Hourly Rate	Hours	Total Pay	Hourly Rate	Hours	Total Pay		**Today's Date**	10/25/21
James P.	15	126	$1,890.00	15	150	$2,250.00		**End Date**	11/29/21
Josh R.	15	120	$1,800.00	15	150	$2,250.00			
Alex H.	15	100	$1,500.00	15	150	$2,250.00			
Jibin M.	15	130	$1,950.00	15	150	$2,250.00			
Labor Subtotal		Subtotal:	$7,140.00		Subtotal:	$9,000.00			
Labor Overhead	Rate:	50%	$3,570.00	Rate:	50%	$4,500.00			
Total Labor			$10,710.00			$13,500.00			
Contract Labor	Hourly Rate	Hours	Total Pay	Hourly Rate	Hours	Total Pay			
Lab Assistant	$40.00	3	$120.00	$40.00	5	$200.00			
Total Contract Labor			$120.00			$200.00			
Material Costs	Quantity	Value	Total Cost						
Breadboard	2	$5.00	$10.00						
LM339 Comparator	2	$0.50	$1.00						
Voltage Regulator	4	$0.75	$3.00						
Jumper Wire Pack	2	$2.00	$4.00						
Plywood	1	$8.00	$8.00						
Resistor	13	$0.13	$1.69						
Fuse Holder	1	$5.00	$5.00						
2A Fuse	5	$1.00	$5.00						
Total Material Costs			$37.69						
Equipment Rental Costs	Value	Rental Rate	Rental Cost	Value	Rental Rate	Rental Cost			
Oscilloscope	$5,300.00	0.20%	$667.80	$5,300.00	0.20%	$1,038.80			
Rover 5	$60.00	0.20%	$7.56	$60.00	0.20%	$11.76			
Function Generator	$16.00	0.20%	$2.02	$16.00	0.20%	$3.14			
Multi-Meter	$149.00	0.20%	$18.77	$149.00	0.20%	$29.20			
Battery Pack	$17.00	0.20%	$2.14	$17.00	0.20%	$3.33			
Basys 3 Artix-7	$150.00	0.20%	$18.90	$958.00	0.20%	$187.77			
IPS Sensor	$8.00	0.20%	$1.01	$8.00	0.20%	$1.57			
IR Sensor	$13.29	0.20%	$1.67	$13.29	0.20%	$2.60			
Color Light to Frequency Convertor	$4.00	0.20%	$0.50	$4.00	0.20%	$0.78			
Power Supply	$1,700.00	0.20%	$214.20	$1,700.00	0.20%	$333.20			
Total Rental Costs			$934.58			$1,612.16			
Total Project Costs			$11,802.27			$15,349.85			

Appendix B

Gantt Chart

Main Project							9/20/2021	9/27/2021	10/4/2021	10/11/2021	10/18/2021	10/25/2021	11/1/2021	11/8/2021	11/15/2021	11/21/2021
Task Name	Done	Josh	James	Jibin	Alex	Location					Interim Presentaio	Interim Report Du	PCB Deadline			
Mini Project	100%	xx	xx	xx	xx	Lab										
EagleCAD Circuit Design	33%	xx	xx	xx	xx	Lab/Internet										
Hardware																
IPS Sensor																
Research	100%	xx	xx	xx	xx	Internet										
Obtain Part	100%	xx				Lab										
Implementation	100%		xx	xx		Lab										
Connectivity	100%		xx	xx		Lab										
IR Sensor																
Research	100%	xx	xx	xx	xx	Internet										
Obtain Part	100%	xx				Lab										
Implementation	100%		xx	xx		Lab										
Connectivity	100%		xx	xx		Lab										
Light to Frequency Convertor																
Research	100%	xx	xx	xx	xx	Internet										
Obtain Part	100%	xx				Lab										
Implementation	0%		xx	xx		Lab										
Connectivity	33%		xx	xx		Lab										
Software																
IPS Sensor																
Research Software Implementation	100%	xx	xx	xx	xx	Internet										
Create Code Implementation	85%	xx			xx	Lab										
Test and Complete Code	0%	xx			xx	Lab										
IR Sensor																
Research Software Implementation	100%	xx	xx	xx	xx	Internet										
Create Code Implementation	85%	xx			xx	Lab										
Test and Complete Code	0%	xx			xx	Lab										
Light to Frequency Convertor																
Research Software Implementation	100%	xx	xx	xx	xx	Internet										
Create Code Implementation	33%	xx			xx	Lab										
Test and Complete Code	0%	xx			xx	Lab										
Final Project Completion																
Finish Circuit Connection to Rover-5	0%	xx	xx	xx	xx	Lab										
Finish and Compile all Software	0%	xx	xx	xx	xx	Lab										
Test Software and Hardware Together	0%	xx	xx	xx	xx	Lab										